Journal of Fish Biology (1996) **49**, 363–366

Agonistic behaviour and sound production in *Gaidropsarus mediterraneus* (Gadidae)

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(*Received 22 July 1995, Accepted 1 December 1995*)

Agonistic behaviour and sound production were described for captive *Gaidropsarus mediterraneus*, a shore-dwelling gadoid. Thump-like sounds were produced during agonistic interactions, which involved disputes over access to shelter sites.

Key words: *Gaidropsarus*; benthic fish; agonistic behaviour; sound production.

Many gadoid species show well-developed agonistic behaviour, and a few species produce sounds during courtship and aggressive encounters (Hawkins & Rasmussen, 1978). From an evolutionary point of view, rocklings are particularly interesting because they depart strongly from the general gadoid mode of life and morphology. Indeed, they present several unique features, such as an elongate body and anguilliform swimming, that allow them to move and feed in close proximity to the substratum. Although previous work on other rocklings, e.g. *Ciliata mustela* (L., 1758) and *Gaidropsarus vulgaris* (Cloquet, 1824), has not provided evidence for sound production (Hawkins & Rasmussen, 1978), the present paper presents a preliminary description of agonistic behaviour and associated sound production in captive *G. mediterraneus* (L., 1758).

Fish were collected at Parede (38°41′ N, 9°22′ W) and Arrábida (38°28′ N, 8°59′ W) on the west coast of Portugal, from October 1992 to December 1994. They were captured underwater at night and in tide pools, with the help of hand nets. Fish size ranged from 13·0 to 28·5 cm SL.

Fish were studied in two different settings. The first setting was used for basic behavioural descriptions. Fish were kept in groups of four and two specimens in 600 l and 100 l aquaria, respectively, provided with a bottom layer of sand. Rocks, bricks and PVC tubes were provided for shelter. Fish were fed with mussels, shrimps, fish meat and squid. The aquaria were placed in a shaded outdoor site without artificial illumination. Temperature ranged from 9° C in the winter to 27° C in the summer. Salinity was kept at 34–36‰. A total of 11 individuals was observed (two of which were used more than once) during 20 h of free observations and 56 h of focal observations (Martin & Bateson, 1993). Videotape recordings were made in order to describe in more detail the fishes behavioural repertoire.

The second setting was used to study sound production and its relation to agonistic behaviour. Two individuals of 13·8 and 20·0 cm SL, captured in December 1994, were placed one in each half of a 100 l aquarium, separated by an opaque partition. A shelter was provided for each fish. The tank was equipped as described above and was kept indoors but under a natural photoperiod. Salinity was at 34‰ and temperature was 15·5° C. Sound production was monitored with a hydrophone (MS.83 Sound Range Hydrophone, Plessey Ltd) with a sensitivity of − 100 dB re 1 V/μbar and with a flat

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0022–1112/96/080363+04 $18.00/0

frequency response up to 40 kHz, placed approximately in the middle of the experimental tank. Sounds were amplified and filtered with a low-noise amplifier (Brookdeal, model 450) and recorded with a digital audiotape recorder (Casio, model DA-1). Before the beginning of each recording session, aeration was stopped and the partition removed, allowing the fish to interact. Both individuals were monitored for a total of five sessions of approximately 30 min each and behaviour was scored for every sound emission. A total of 64 sounds was analysed with a Loughborough Sound Images Workstation (version 2.0; Metagraphics Software Corporation©). The following sound features were measured: fundamental and maximum frequency (Hz) (filter bandwidth, 15 Hz); peak frequency (frequency at the highest sound amplitude, Hz) (filter bandwidth, 125 Hz); pulse and sound duration (ms); interval between sounds (ms), when produced in series. Because recordings were carried out in a small tank, sound duration measurements should not be taken as precise values due to possible reverberation from the tank walls (Parvulescu, 1967). In addition, pulse structure was not always clear, limiting the sample size of pulse duration measurements.

During 80·4% of the observation time the fish rested on the bottom, usually in holes or crevices, sometimes with one side contacting the walls of the shelter. Fish were also observed to excavate spaces beneath rocks by digging out sand. Most agonistic interactions were observed when a fish approached or intruded upon an already occupied shelter (84·5%; $n=55$). The dominant fish of each group often moved around the tank visiting the available shelter sites, dislodging the current occupants. The behavioural patterns observed during agonistic encounters were summarized as follows.

(1) Threatening: one fish resting on the bottom, often in a shelter, threatened an approaching intruder by turning its head towards it, with fully open pectoral fins. In many instances this action was sufficient to induce flight. Mouth opening was not observed during threatening.

(2) Low intensity charging and butting: a fish swam at moderate speed towards the opponent, touching it on one flank or the posterior part of the body, with the mouth closed.

(3) Biting: biting was usually preceded by a charge, in which the fish swam quickly towards the opponent. The biting fish seized the opponent and the grip could last up to 4 s. The bitten fish responded by performing spiral movements along its body axis, which apparently helped it to get free. Biting frequently caused injuries with loss of scales.

(4) Chasing: a fish swam rapidly towards and after the opponent, making it flee with sudden changes in direction.

(5) Circle fighting: two fish swam in a carousel, in an anti-parallel orientation, with each fish attempting to bite each other's tail. They were observed to describe three to seven circles in this way. Circle fighting ended when one fish fled, sometimes being chased by the opponent.

Only thump-like sounds were heard from the two fish, usually accompanying chasing and biting behaviours. These aggressive interactions and acoustic emissions were always a result of the smaller fish approaching or intruding upon the larger fish's shelter. Only 16·9% of the interactions could not be observed because they took place behind the shelter. Which of the two participants in an encounter produced the sounds recorded could not be determined with certainty.

Results of the sound analysis are presented in Table I, and a sonogram and oscillogram of a typical thump is shown in Fig. 1.

These observations suggest that *G. mediterraneus* displays convergent behavioural similarities with other benthic resident fish of the rocky littoral, in which agonistic behaviour is often related to patterns of space occupancy and disputes over access to shelter sites (Gibson, 1968). Digging in this gadoid may also be viewed as another convergent similarity with benthic littoral fish because it is also observed in *C. mustela*, another rockling common in tide pools (pers. obs.). During nocturnal dives and aquarium observations, fish seemed much more active than during daytime (pers. obs.); thus a full appreciation of the functional role of agonistic behaviour will probably require careful nocturnal observations using infra-red video and hydrophone recordings, as described by Brantley & Bass (1994).

TABLE 1. Sample size (n), mean, median, standard deviation (S.D.), minimum (min) and maximum (max) of the features (see text for explanations) of a thump produced by *Gaidropsarus mediterraneus*

	n	Mean	Median	S.D.	Min.	Max.
Sound duration (ms)	64	80·969	77·200	30·515	27·5	197·9
Pulse duration (ms)	44	6·859	6·500	1·691	4·6	13·1
Peak frequency (Hz)	64	180·953	152·000	75·901	82·0	409·0
Min frequency (Hz)	61	47·951	47·000	16·092	23·0	105·0
Max frequency (Hz)	61	736·279	737·000	249·604	251·0	1673·0
Interval between sounds (ms)	36	1004·981	773·950	923·013	51·4	3178·9

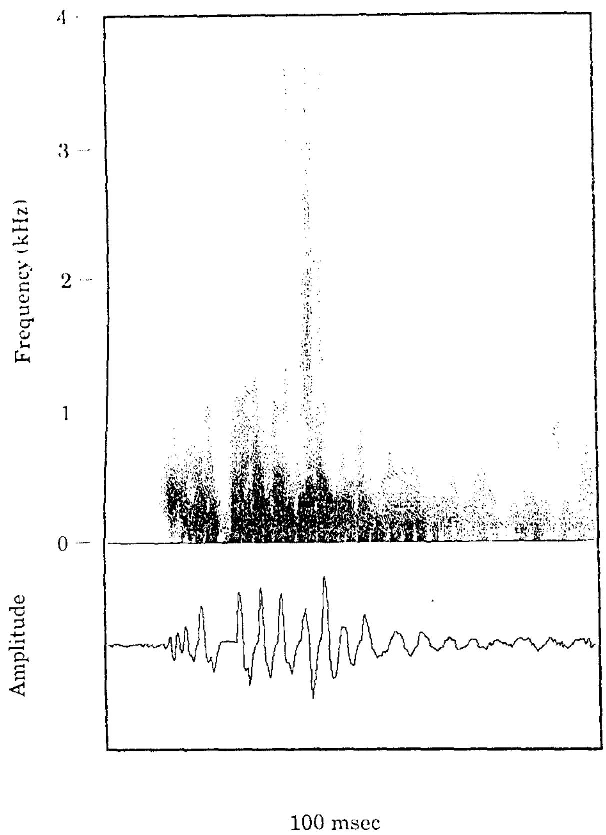

FIG. 1. Sonogram and oscillogram of a thump produced by *Gaidropsarus mediterraneus* (filter bandwidth = 125 Hz).

Although Hawkins & Rasmussen (1978) concluded that the smaller species of gadoids were non-vocalists, probably to lessen vulnerability to predation, evidence is presented here that the shore rockling is capable of sound emission. The mechanism of sound production in this species is not clear due to the absence of the drumming muscles (pers. obs.) which are clearly evident in all other vocal gadoids (Hawkins & Rasmussen, 1978). Nevertheless, the swimbladder may still be involved in sound production through being vibrated under the direct action of body muscle contraction (Tavolga, 1971).

This study was partially supported by Junta Nacional de Investigação Científica under the project (PBIC/C/MAR/1313/92) and (BD/2346/92-IG, programme Ciência); Fundação Calouste Gulbenkian and Instituto Português da Juventude. The authors are also grateful to Fátima Gil, and Emanuel Gonçalves for their help, and to Dr A. D. Hawkins for reviewing this paper and to Dr Winfield and two referees for their helpful comments, criticisms and suggestions.

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